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Ecological factors affecting collembola populations. Ordination of communities

BY

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Synopsis: The Collembola populations of five different plant communities (beech, oak, pine, eucalyptus and meadow, have been studied by means of the analysis of correspondences and cluster methods. It is possible to group in a same context the deciduous and eucalyptus forests, separating them from the pine and from the meadow.

Keywords: Collembola - plant communities - ecological factors - analysis of correspondences - cluster analysis.

INTRODUCTION

Sometimes, the distribution and abundance of certain species of collembola, in particular ecosystems, play an indicator role of the environmental conditions, responding to them in terms of abundance and frequency variations.

The multivariate analysis, particularly the analysis of correspondences, repeatedly applied on collembolan populations (ANDRÉ, 1983; ARPIN *et al.*, 1984; BONNET *et al.*, 1977, 1979; GERS, 1982; GERS & IZARRA, 1983; PONGE, 1980, 1983; PONGE & PRAT, 1982; POURSIN & PONGE, 1982, 1984; POZO & SIMON, *in press*; PRAT & MASSOUD, 1980), allows to detect latent factors that affect the distribution and abundance of collembolan species.

This statistical technique constitutes an essential tool when dense data tables are analysed. Otherwise, a lot of information would go unnoticed.

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Similarity measures, sometimes forgotten by ecologists, are highest utility elements (LEGENDRE & LEGENDRE, 1979) and establish the groundwork of cluster analysis.

This paper present the results of the use of both types of analysis upon the populations of collembola collected from five different ecosystems of The Basque Country (Spain).

I. — MATERIAL AND METHODS

Sites location and sampling have been described in previous works (POZO & MARTINEZ, 1983; POZO *et al.*, 1986). However, it must be noticed that this work is based on the study of collembola populations of several plant communities of The Basque Country, Spain:

A) Beechwood, *Fagus silvatica* L. Edaphic characteristics: Organic matter, 7.47 %; C/N, 18,56; pH, 4.78.

B) Oakwood, *Quercus robur* L. Edaphic characteristics: Organic matter, 5.23 %; C/N, 23.58; pH, 5.12.

C) Pine forest, *Pinus silvestris* L and *Pinus pinaster* (Soland). Edaphic characteristics: Organic matter, 13.26 %; C/N, 29.56; pH, 5.08.

D) Eucalyptus forest, *Eucalyptus globulus* (Labill). Edaphic characteristics: Organic matter, 7.16 %; C/N, 24.90; pH, 4.93.

E) Meadow. Edaphic characteristics: Organic matter, 6.51 %; C/N, 18.36; pH 5.37.

The edaphic characteristics are summarized from POZO (1983 and POZO *et al.* (1986) and correspond to the 0-5 cm of soil depth.

Samples were taken in months representing the 4 seasons of the year: November 1980, February, May and August 1981. Each month, 6 samples of litter and 6 of soil (0-5 cm depth) of about 250 ml were taken.

For studying collembola according to statistical treatments, the factorial analysis of correspondences (LEBART & MORINEAU, 1982) was used. In the program the RECIP stage was include to allow the construction of a hierarchical classification of the samples.

This analysis was applied upon a data matrix composed of 40 season-layer, obtained from the union of the 6 samples of each layer (litter or soil) at each season, and of the 37 species present at least in 5 of these composed samples. The groupement of similar samples, when the analysis of correspondences is used, has been employed by many authors (GERS, 1982; PONGE & PRAT, 1982; POURSIN & PONGE, 1982, 1984).

II. — RESULTS AND DISCUSSION

The distribution of samples and species in the factorial plane of the axis 1 and 2 of the analysis of correspondences (Fig. 1) shows three well differentiated groups. The deciduous forests and the eucalyptus stand are grouped in the negative part of the axis 1. The pinewood (positive values of the axis 2) and meadow (negative values of the axis 2) are distributed in the positive part of the same axis.

This disposition of the areas with relation to axis 1 could be attributed to an hydric factor, which coincides with the clear opposition between the eucalypt forest, with a soil under drier conditions, and the pinewood, whose soil has a higher hydric retention (Pozo, 1983). An interpretation of the axis 1 as a water content factor is reinforced by the position of *Isotomurus palustris* (IPA), located in the positive end of this axis. The hygrophily of this species is well-known, and many authors have shown their indicator role about a high moisture of the habitat (e.g.: PONGE, 1980, 1983; PIART & DUVIARD, 1985).

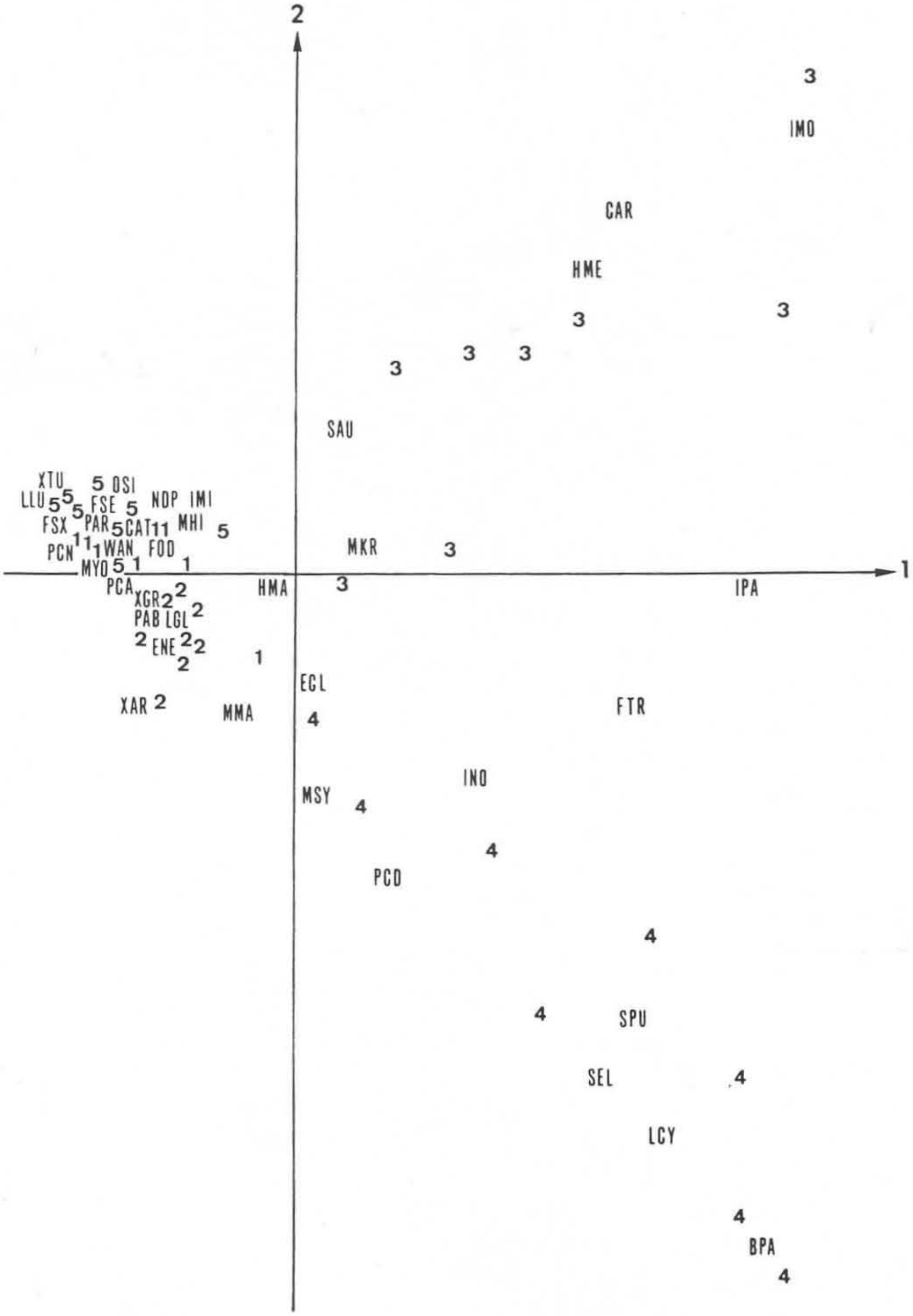

FIG. 1. — Analysis of Correspondences. Distribution of samples and species. Axis 1 and 2. Samples code: 1 = Beechwood; 2 = Oakwood; 3 = Pinewood; 4 = Meadow; 5 = Eucalyptus forest. For species code see species dictionary (Appendix II).

In another hand, the distribution of the samples and species coincides, in a certain way, with a separation of the sites according to the soil pH. Beechwood and eucalypt forest with averages values below 5 are located on the left side, whereas pinewood and meadow (pH > 5) are on the right side. Even in a small variation of the soil pH, it seems that the 5 pH value could be a boundary suitable for radical change in species composition (PONGE, 1983). The acid conditions of the soils are denoted by the presence of species whose acidophily has been repeatedly stated by several authors. In this sense, *Willemia anophthalma* (WAN), in the beechwood, and *Lipothrix lubbocki* (LLU), in the eucalyptus forest, would show these conditions (ARPIN *et al.*, 1984; PONGE, 1980; PONGE & PRAT, 1982; POURSIN & PONGE, 1984). The same happens to *Xenylla tullbergi* (XTU), inhabiting acid litters according to PONGE (1983), which here setles the eucalyptus litter. *Onychiurus silvarius* (OSI) and *Protaphorura armata* (PAR), in the eucalypt forest, and *Protaphorura cancellata* (PCN), in the beechwood, can be included with them. Both the latter belong to a genus of clear acidophily trend (PONGE, 1983). Another species that may show important population densities, in soils where litter is accumulated by the existence of a low biogical activity and under acid conditions, is *Mesaphorura yosii* (PONGE, 1980, 1983). In our case, *M. yosii* (MYO) is practically restrained to the eucalyptus stand, under high C/N ratios and acid conditions.

The axis 2 could be interpreted as a transition from open environments to those which remain under similar conditions of shade during the whole year. It could be expected a more distant position of the eucalypt forest from the deciduous, in relation to axis 2, because, although the season-layers of that forest are in the main located in the upperpart of the cloud of points, they belong to the group where those of deciduous are located. This situation leads to think that this plantation of *Eucalyptus globulus* has not succeeded in eradicating the collembological community of this area, that recalls the deciduous mixed forest which could exist previously according to the shoots of present vegetable species (unpublished data).

In another hand, many authors have also stated, when applying correspondence analysis to collembolan populations, the presence of an axis which has been interpreted as a gradation or opposition between open and cover areas (BONNET *et al.*, 1979; GERS & IZARRA, 1983; PONGE, 1980). Our results coincide to a great extent with those of them. It is possible to define a group of species which characterizes the site they inhabit (Fig. 1). Thus, we could consider *Brachystomella parvula* (BPA), *Lepidocyrtus cyaneus* (LCY), *Sphaeridia pumilis* (SPU) and *Sminthurinus elegans* (SEL) as species of open areas (meadow). Opposite to this group, three species, *Isotoma monochaeta* (IMO), *Ceratophysella armata* (CAR) and *Hypogastrura meridionalis* (HME) are perfectly differentiated, denoting the shade of pine forest. Between both extrema are placed the deciduous forests, where high densities of *Folsomia quadrioculata* (FOD) and *Folsomia sexoculata* (FSX) occur. The intermediate position of *I. palustris* (IPA), in relation to axis 2, aggrees with the results exposed by PONGE (1980); it is a species which can colonize moist open sites but it is more abundant in forests, here in the pinewood.

Axis 3 was basically marked by *Xenyllodes armatus* (XAR), whose absolute contribution to the axis was of 45.3 %, probably due to an aggregate of individuals in one of the winter samples of soil (0-5 cm depth). So, this axis has not been taken into account for interpretation and has not been plotted.

Axis 4 has been interpreted as vertical distribution, separating soil and litter layers, what implies an species disposition according to the particular microhabitat in each ecological system. Depth can be considered as a very important ecological factor for the fauna distribution (Gers, 1982; Gers & Izarra, 1983; Ponge, 1980; Poursin & Ponge, 1982, 1984; Prat & Massoud, 1980).

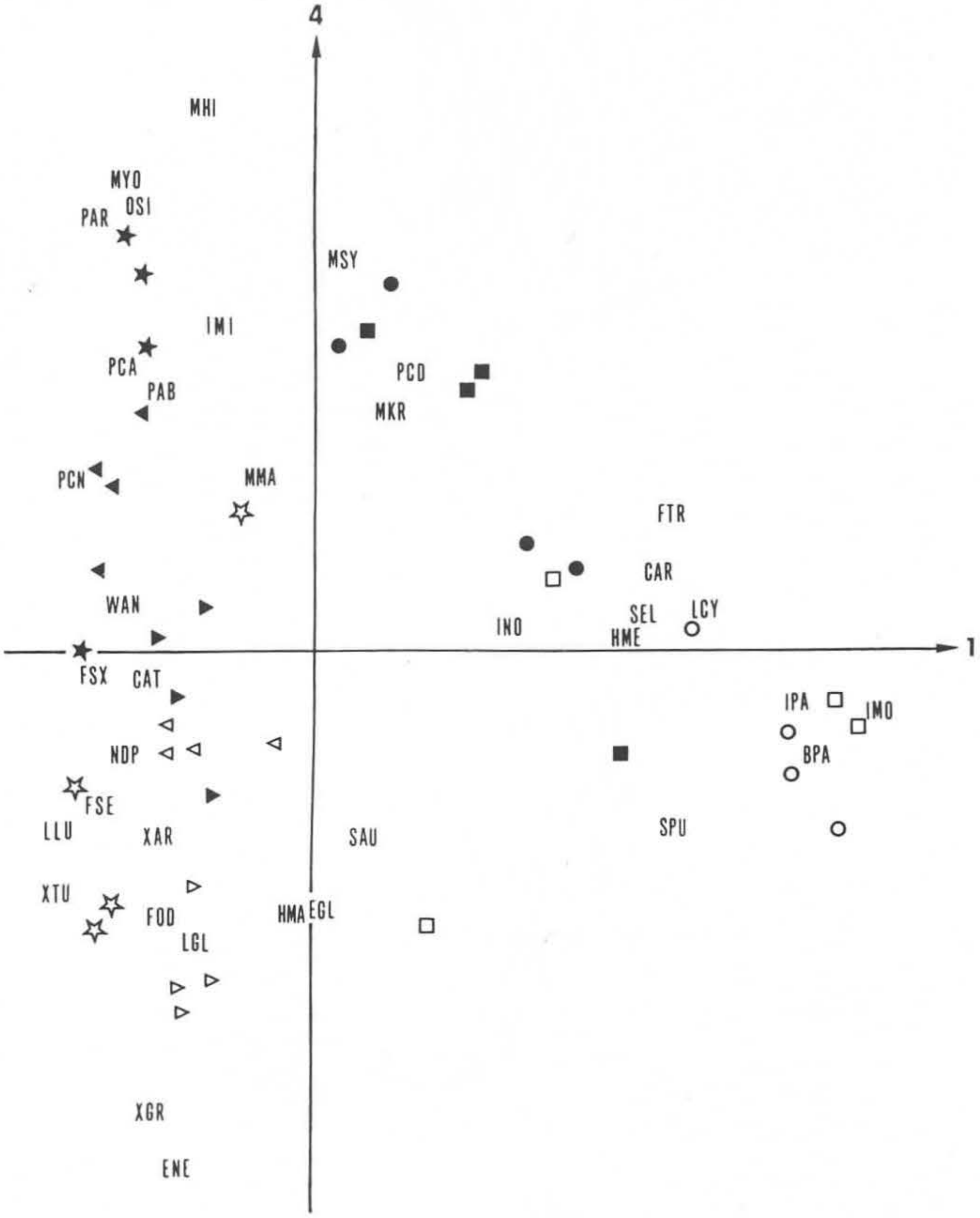

Fig. 2. — Analysis of Correspondences. Distribution of samples and species. Axis 1 and 4. Samples code: ◁ = Beechwood litter; ◀ = Beechwood soil; ▷ = Oakwood litter; ▶ = Oakwood soil; □ Pinewood litter; ■ = Pinewood soil; ○ = Meadow herbaceous layer; ● = Meadow soil; ☆ = Eucalyptus forest litter; ★ = Eucalyptus forest soil. For species code see species dictionary (Appendix II).

Figures 2 and 3 represent the samples and species distribution in the planes formed by the axis 1-4 and 2-4, respectively. Both have in common that it persists a grouping of deciduous and eucalypt forests which differs from the other two ecosystems types, whether it refers to aspects of soil (1-4) or to the type of plant community (2-4), always keeping apart litter from soil. From these figures arises a group of species associated to the superficial layer such as *B. parvula* (BPA), *S. pumulis* (SPU), in the meadow, *Xenylla grisea* (XGR), *X. tullbergi* (XTU), *F. quadrioculata* (FQD), *Entomobrya* gr. *lanuginosa* (ELA), *Entomobrya nevadensis* (ENE), *Heteromurus major* (HMA), *Lepidocyrtus* gr. *lanuginosus* (LLA), *Sminthurinus aureus* (SAU), *L. lubbocki* (LLU), in the deciduous and eucalypt forest (see appendix I) and *I. monochaeta* (IMO), in the pine forest. *I. palustris* (IPA), which appears preponderantly in the litter layer, wherever, must be added to them. In the other end, the edaphic characteristics are determined mainly by *Mesaphorura sylvatica* (MSY), whose no individuals were collected in the superficial layers of any site. This distribution in depth of *M. sylvatica* have been observed by other authors (ARPIN *et al.*, 1984; HÅGVAR, 1983; PONGE, 1980; POURSIN & PONGE, 1982). Its greatest densities were attained in meadow, oakwood and pinewood, systems having the highest pH values in soil, although in all this soils the humification processes do not occur in the same way, since the C/N ratios are higher in pinewood and oakwood than in

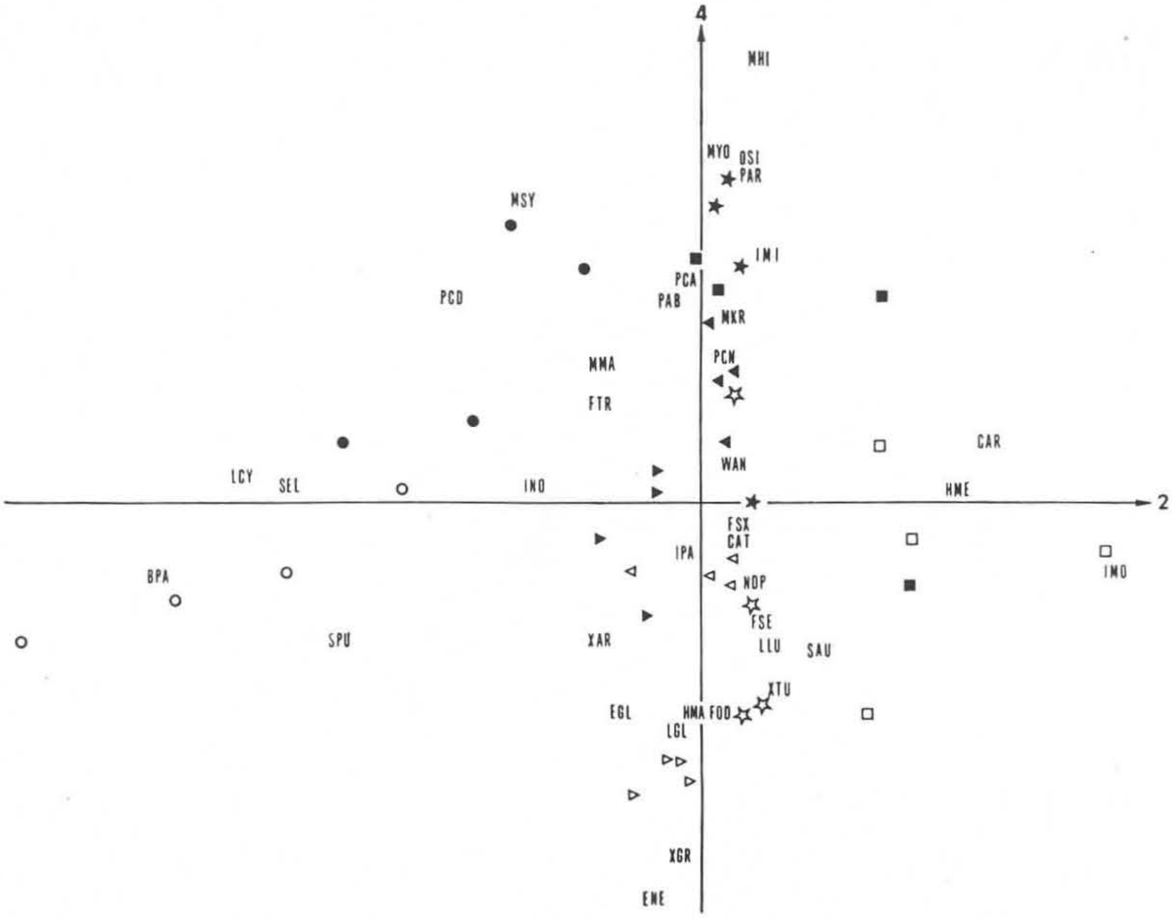

FIG. 3. — Analysis of Correspondences. Distribution of samples and species. Axis 2 and 4. The samples code is the same that in figure 2. Species code is in appendix II.

meadow. Other species that have shown this edaphic trend have been *Paratullbergia callipygos* (PCA), *O. silvarius* (OSI), *P. armata* (PAR), *P. cancellata* (PCN), *Isotomiella minor* (IMI), *Pseudosinella alba* (PAB) and *Pseudosinella* cf. *decipiens* (PCD).

No axis has been found that could be interpreted as a seasonal factor, although in figures 2 and 3 some samples of soil are inserted in those of litter. They correspond to summer, that must be understood as a consequence of the hydric deficit that compels the litter species to migrate to deeper layers, looking for a wetter environment (Pozo *et al.*, 1986), with the result that this season has a specific composition more similar to the superficial layers in other seasons of the year.

The dendrogram of figure 4 shows the clusters established among the 40 season-layers according to the ecological affinities on the basis of species composition. Although in this figure they are represented three main groups, these enclose some subgroups that must be explained. First, it must be pointed out the cluster formed by beech and eucalypt forests, essentially on the basis of the litter layer. The species that contribute to this association are mainly *F. quadrioculata*, *F. sexoculata* and *Folsomia setosa*. This three species also coexist in deciduous forest from neighbouring regions (ARBEA & JORDANA, 1985).

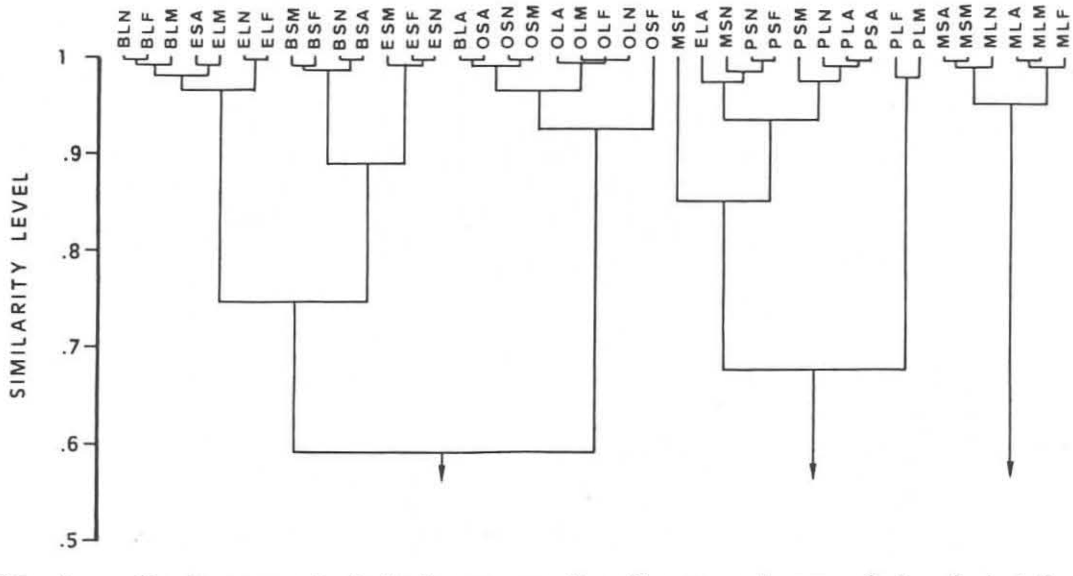

FIG. 4. — Dendrogram of similarity among the 40 seasons-layers. Code: first letter, O = Oakwood, B = Beechwood, P = Pinewood, M = Meadow, E = Eucalyptus forest; second letter, L = Litter or Herbaceous layer, S = Soil; third letter, N = November, F = February, M = May, A = August.

Next, season-layers of the same forests are joined to the previous cluster, bringing a common edaphic component based on *P. callipygos*, *I. minor* and *Mesaphorura macrochaeta*. It must be noticed, however, that the soils of both sites present a collembological edaphic difference given by the presence of *P. armata* and *O. silvarius*, in the eucalyptus stand, and of *P. cancellata*, in the beechwood. Until the 0.6 similarity level, the season-layers of the oakwood form a cluster apart, due, without doubt, to the great importance of *X. armatus*. However, this forest meets the two forests cited above by species such as *F. quadrioculata*, *F. sexoculata* and *M. macrochaeta*.

The pinewood forms a separate cluster in figure 4. Obviously it is an ecological system that differ from the other areas. The species of collembola responsible of this difference are *C. armata*, *H. meridionalis*, *Mesaphorura krausbaueri* and *I. monochaeta*. Some season-layers of meadow and eucalyptus forest become associated to this cluster due to *M. krausbaueri*.

Finally, the separation of the meadow from the rest of the ecological systems is mainly caused by the great importance of *B. parvula* and, to a less extent, by *Lepidocyrtus cyaneus*.

The groups resulting from the cluster analysis are, to great extent, according to the results obtained by the analysis of correspondences, showing three types of communities: first, deciduous and eucalyptus forests; second, pine forest and finally, the meadow.

According to the results of other authors, the group formed by deciduous and eucalyptus forests, shows that the collembolan populations are, in a certain way, independent of the corresponding tree population (PONGE, 1980, 1983; POURSIN & PONGE, 1984), and the relationship between soil and fauna should be find out in the humification type. However, it is evident that between beechwood soil and eucalptus forest soil, under similar acid conditions, there are differences respecting to the C/N ratios that indicate a poorer biological incorporation of the organic matter, typical of moder humus, in the eucalyptus forest soil. The litter accumulation, that occur in eucalyptus and pine forests, and the high C/N ratios should indicate a humification of moder or mor type, different from the other areas, more peculiar of mull type. Perhaps it should be expected a correspondence of collembological communities in this sense, however, the hydric factor, the soil acidity conditions and, perhaps, edaphic-biological processes no detected in this study, are important parameters that influence the ordination of communities.

ABSTRACT

The collembolan populations of five plant communities of The Basque Country (Spain) have been studied by means of the utilization of analysis or correspondences and cluster analysis.

The multivariate analysis enabled to detect some latent ecological factors which, influencing the collembolan populations, contribute to an ordination of communities. Those factors seem to be, mainly, the water content, soil pH, open/cover areas and depth.

Results enable to distinguish three types of communities on the basis of species of Collembola. The first one groups deciduous forests (beechwood and oakwood) and eucalypt forest. The second and third area are the meadow and the pine forest.

RESUMEN

Factores ecologicos que afectan a las poblaciones de Colembolos. Ordenacion de comunidades

Las poblaciones de Colémbolos de cinco comunidades vegetales del País Vasco (España) han sido estudiadas mediante la utilización de análisis de correspondencias y análisis de « cluster ».

El análisis multivariable ha permitido detectar una serie de factores ecológicos latentes que, al influir sobre las poblaciones de Colémbolos, contribuyen a una ordenación de comunidades. Estos factores parecen ser, principalmente, el contenido hídrico, el pH del suelo, area abiertas/cubiertas y profundidad.

Los resultados permiten distinguir tres tipos de communidades en función de las especies de Colémbolos. La primera de éllas agrupa bosques caducifolios (hayedo y robledal) y una plantación de eucaliptos. En segundo término, se diferencia una comunidad de pinar. Finalmente, una comunidad de prado.

RÉSUMÉ

Facteurs écologiques affectant les peuplements des Collemboles. Ordination des communautés

Les peuplements de Collemboles de cinq communautés végétales du Pays Basque (Espagne) ont été étudiés à l'aide de l'analyse des correspondances et au moyen de l'analyse de « cluster » (groupement).

L'analyse multidimensionnelle a permis de détecter un ensemble de facteurs écologiques latents qui influencent les peuplements de Collemboles et contribuent à une ordination des communautés. Ces facteurs sont le pH du sol, la teneur en eau, le milieu ouvert/milieu forestier et la profondeur.

Les résultats permettent de distinguer trois types de communautés en fonction des espèces de Collemboles. D'une part, un ensemble de forêts de feuillus (hêtre, chêne) et de forêts d'eucalyptus, d'autre part, une communauté de prairie et enfin, une communauté de forêts de pins.

APPENDIX I

Abundances of each species in the 40 seasons-layers

	Seasons-layers															
Species	BLN	BLF	BLM	BLA	BSN	BSF	BSM	BSA	OLN	OLF	OLM	OLA	OSN	OSF	OSM	OSA
HME		7														
CAR	3		7		1		1	4	1				3		1	2
CAT	2	46	1			14	1		2							2
XGR		1	1						22	17	13	37				
XTU																
WAN	3	2	5			2	6	5								
FTR																
XAR									67	27	96	58	21	595	84	38
BPA		4	6													3
NDP	6					2	1		1							1
PCN	12	7	10		82	27	20	65	9					1	2	
PAR						7		1								
OSI																
PCA	1				128	48	49	25	2				22	81	84	14
MKR						13	14	2		1		1	13	59	7	2
MMA			1	3	40	32	27	18			1		35	177	90	50
MSY						9	5	6						52	10	1
MYO																

APPENDIX I *(Continuation)*

MHI														1		
FQD	44	51	56	1	9	3	30	9	208	59	193	74	32	108	117	95
FSE	68	14	10		22	9	5									
FSX	90	81	112	5	226	75	257	128	4	10	24	15	7	27	39	58
IMI	35	30	16	2	46	54	20	21	6				2	33	17	7
IMO											2					2
INO	12	10	27	8	2	7	4	5	15	6	15	16	3	12	2	56
IPA		5	5				2		8		15		1		2	
ELA	1	1	13					2	1		13	33				
ENE									5	4	8	6	1			
HMA	13	3	1	5		2			13	2		9				10
LCY	1															
LLA	9	4	10	5	1			4	8	4	7	38			2	75
PAB	1		1		12	3	1	30							1	
PCD	2				1	2	2									
SPU	10	1								1	8	7				
SAU	33	10	7		2				5	19	34		1	2	3	
SEL	1		2													
LLU	1															1

	Seasons-layers															
	PLN	PLF	PLM	PLA	PSN	PSF	PSM	PSA	MLN	MLF	MLM	MLA	MSN	MSF	MSM	MSA
Species																
HME		13	6	3	3	4	23	38								
CAR	54	52	99		5	2	132	46		1					2	1
CAT																
XGR										1		4				
XTU																
WAN																
FTR	7	21	12		19	66	12	17	83	120	9		6	1		
XAR																
BPA								12	97	339	77	67	3	10	17	18
NDP	1					1										
PCN																
PAR																
OSI																
PCA					13				3				20	16	14	1
MKR	72	39	13		29	133	71		8	6			36	77	20	11
MMA		3			12	29	6		31	27			68	97	19	7
MSY					12	6	5	3					4	204	9	2
MYO										1						
MHI						4	2									
FQD	26		15	10	8			67								
FSE																
FSX																
IMI	36	1			33	70	141									
IMO	61	259	561	5	1	32	24	84								
INO	21	23	32		1	30	13	15	83	103	21		9	88	117	12
IPA	24	330	82		3	13	14		58	200	9		5	8	17	2
ELA			6	2				2	1	9	2	1		2	4	9
ENE																
HMA		1	2	1				7	5							

APPENDIX I *(End)*

LCY									4	29				3	13	21
LLA				1		1		8								
PAB										2			4		3	3
PCD												1	12	4	4	9
SPU		2	6						14	47	27				2	
SAU	37	28	17			3										
SEL										9	2			4	1	2
LLU																

	Seasons-layers							
	ELN	ELF	ELM	ELA	ESN	ESF	ESM	ESA
Species								
HME								
CAR	5	7	1		1		1	
CAT								
XGR	17	60		1				
XTU	106	233	177	42				115
WAN								
FTR								
XAR								
BPA	1							
NDP	2		3					
PCN								
PAR	1	1	2		32	26	47	21
OSI		5	2		11	15	29	
PCA	2	19	1		142	112	64	39
MKR				242			3	29
MMA		2	14	9	6	52	50	8
MSY						1		
MYO	3	1			7	24	1	
MHI					16		1	
FQD	37	265	223	2	2	15	32	
FSE	4	124	32		3	14	11	
FSX	55	155	778	166	45	28	127	294
IMI	8	21	23		94	111	229	14
IMO								
INO	4	14	11	10	2	1	2	7
IPA	1	5	6			1	3	
ELA	5	5	11	2	1			1
ENE								
HMA								
LCY								
LLA		4	8		1			
PAB					1	7		2
PCD								
SPU		4					1	2
SAU	11	2	19				2	
SEL								
LLU	5		56	7			1	

APPENDIX II

Species dictionary

HME = *Hypogastrura meridionalis* Steiner, 1955.
CAR = *Ceratophysella armata* (Nicolet, 1941).
CAT = *Ceratophysella attenuata* Cassagnau, 1959.
XGR = *Xenylla grisea* Axelson, 1900.
XTU = *Xenylla tullbergi* Börner, 1903.
WAN = *Willemia anophthalma* Börner, 1901.
FTR = *Friesea truncata* Cassagnau, 1958.
XAR = *Xenyllodes armatus* Axelson, 1903.
BPA = *Brachystomella parvula* Schäffer, 1896.
NDP = *Neanura (Deutonura) plena* Stach, 1951.
PCN = *Protaphorura cancellata* Gisin, 1952.
PAR = *Protaphorura armata* (Tullberg, 1869).
OSI = *Onychiurus silvarius* Gisin, 1952.
PCA = *Paratullbergia callipygos* (Börner, 1902).
MKR = *Mesaphorura krausbaueri* Börner, 1901 *sensu* Rusek, 1971.
MMA = *Mesaphorura macrochaeta* Rusek, 1976.
MSY = *Mesaphorura sylvatica* (Rusek, 1971).
MYO = *Mesaphorura yosii* (Rusek, 1967).
MHI = *Mesaphorura higrophila* (Rusek, 1971).
FQD = *Folsomia quadrioculata* (Tullberg, 1871).
FSE = *Folsomia setosa* Gisin, 1953.
FSX = *Folsomia sexoculata* (Tullberg, 1871).
IMI = *Isotomiella minor* (Schäffer, 1896).
IMO = *Isotoma monochaeta* Kos, 1942.
INO = *Isotoma notabilis* Schäffer, 1896.
IPA = *Isotomurus palustris* (Müller, 1776).
ELA = *Entomobrya* gr. *lanuginosa* (Nicolet, 1841).
ENE = *Entomobrya nevadensis* Steiner, 1959.
HMA = *Heteromurus major* (Moniez, 1889).
LCY = *Lepidocyrtus cyaneus* Tullberg, 1871.
LLA = *Lepidocyrtus* gr. *lanuginosus* (Gmelin, 1788).
PAB = *Pseudosinella alba* (Packard, 1873).
PCD = *Pseudosinella* cf. *decipiens* Denis, 1924.
SPU = *Sphaeridia pumilis* (Krausbauer, 1898).
SAU = *Sminthurinus aureus* (Lubbock, 1862).
SEL = *Sminthurinus elegans* (Fitch, 1863).
LLU = *Lipothrix lubbocki* (Tullberg, 1872).

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